

534281

Final Report 5/97 – 6/01

NASA NAG5-5176

Total Budget (\$148,524)

Global Bathymetric Prediction for Ocean Modeling and Marine Geophysics

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Original Proposal Summary

We proposed to construct a complete bathymetric map of the oceans at a 3-10 km resolution by combining all of the available depth soundings collected over the past 30 years with high resolution marine gravity information provided by the Geosat, ERS-1/2, and Topex/Poseidon altimeters. Detailed bathymetry is essential for understanding physical oceanography and marine geophysics. Currents and tides are controlled by the overall shapes of the ocean basins as well as the smaller sharp ocean ridges and seamounts. Because erosion rates are low in the deep oceans, detailed bathymetry reveals the mantle convection patterns, the plate boundaries, the cooling/subsidence of the oceanic lithosphere, the oceanic plateaus, and the distribution of off-ridge volcanoes.

We proposed to:

- (1) Accumulate all available depth soundings collected over the past 30 years. (funded by NSF)
- (2) Use the short wavelength (< 160 km) satellite gravity information to interpolate between sparse ship soundings.
- (3) Improve the resolution of the marine gravity field using enhanced estimates along repeat altimeter profiles together with the dense altimeter measurements.
- (4) Refine/Improve bathymetric predictions using the improved resolution gravity field and also by investigating computer-intensive methods for bathymetric prediction such as inverse theory.
- (5) Produce a *Globe of the Earth* similar to the globe of Venus prepared by the NASA Magellan investigation. This will also include the best available digital land data.

Executive Summary of Results

In November 2000 we completed version 82 of a global topography grid based on all publically-available ship soundings and a new marine gravity model derived from Geosat, ERS and Topex satellite altimeter data. This involved items (1) – (4) above which have all

been completed. We began to construct a globe based on the new global seafloor topography as described in item (5) but found this was already done by a company *Delorme Inc.* (see <http://www.delorme.com/eartha>). All results can be accessed through the web in three forms: (a) original digital depth soundings; (b) global grids of marine gravity and seafloor depth; (c) images and maps in a variety of formats; and (d) general articles and scientific manuscripts. (see <http://topex.ucsd.edu>).

Articles and Publications

- Sandwell, D. T. and W. H. F. Smith, Marine Gravity from Geosat and ERS-1 Altimetry, *J. Geophys. Res.*, 102, 10039-10054, 1997.
- Smith, W. and Sandwell, D., Measured and Estimated Seafloor Topography (version 4.2), World Data Center A for Marine Geology and Geophysics, research publication RP-1, poster 34"x53", 1997.
- Smith, W. H. F. and D. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, *Science*, 277, p.1956-1962, 1997.
- Yale, M.M., D. T. Sandwell and A.T. Herring, What are the limitations of satellite altimetry?, *The Leading Edge*, 17, no. 1, p. 73-76, 1998.
- Yale, M. M., D. T. Sandwell, Stacked global satellite gravity profiles, *Geophysics*, 64, 1748-1755, 1999.
- Sandwell, D. T., W.H.F. Smith, Bathymetric Estimation., Chapter 12 in *Satellite Altimetry and Earth Sciences*, ed., L.L. Fu and A. Cazenave, Academic Press, International Geophysical 69, 441-457, 2001.
- Gille, S. T., M. M. Yale and D. T. Sandwell, Global correlation of mesoscale ocean variability with seafloor roughness from satellite altimetry, *Geophys. Res. Lett.*, 27, no.9, 1251-1254, 2000
- Lyons, S.N., D. T. Sandwell and W. H. F. Smith, Three-dimensional estimation of elastic thickness under the Louisville Ridge, *J. Geophys. Res.*, 105, 13239-13525, 2000.
- Sandwell, D. T., Exploring the Earth from Mars, essay to be published in *History of Plate Tectonics*, ed. N. Oreskes and LeGrand, Columbia University Press, 2001.
- Sandwell, D. T., Smith, W. H. F., Gille, S., and Soofi, K., Bathymetry from Space: White paper in support of a high-resolution, ocean altimeter mission, http://topex.ucsd.edu/marine_grav/white_paper.pdf

Progress for Year 1

Marine Gravity Research:

- We have completed the gravity field recovery along repeat tracks of Topex/Poseidon, ERS-1/2 and Geosat/ERM and have made the data available (delivered) the data through the Internet. The initial results were published in *The Leading Edge* which is a publication of the Society of Exploration Geophysicists. High accuracy shipboard gravity measurements from the Gulf of Mexico, provided by EDCON Corporation, were used to estimate the accuracy and resolution of the satellite-derived gravity data. We find rms agreement at a level of 3 to 5 mGal and are preparing a more complete analysis for publication in *Geophysics*.
- NASA funding was used to combine high resolution grids of bathymetry and topography with our bathymetric predictions in the deep ocean to make a global grid at a uniform resolution (2 minutes). One minute bathymetric grids of selected small areas were provided by the Naval Oceanographic Office (DBDBV) and higher resolution land topography was provided by the USGS (GTOPO-30). This global topography grid (version 6.2) has been supplied to hundreds of users. Applications include; K-12 education, video productions, architectural design, basic research, and oil exploration. A variety of formats are available on our web site (http://topex.ucsd.edu/marine_topo).

- We have not yet updated our data bases of ship soundings because there was no student available to work on this project. This summer Lydie Sichoix will join us as a Post Doc and will devote a large part of her time to this data assembly issue.

Meetings and Publications:

- Yale, M.M., D.T. Sandwell, and A.T. Herring, What are the Limitations of Satellite Altimetry?, *Leading Edge*, 17, 73-76, 1998.
- Yale, M.M., D.T. Sandwell, Stacked Marine Gravity Profiles from Topex and ERS Satellite Altimetry, *EOS Trans., AGU*, v.78, no. 46, p. F151, 1997.

Progress for Year 2

- We have completed a new 1-minute gravity anomaly grid based on all Geosat ERS and Topex altimeter profiles (version 9.1). The main improvements were to back-off on the low-pass filters applied to the data. The along-track filter applied to all of the Geosat, ERS, and Topex along-track data was changed to 0.5 gain at 12 km from a 0.5 gain at 18 km. The two-dimensional filter cutoff wavelength was reduced by a factor of 0.7 at all latitudes. East-west trending features may contain wavelengths as short as 12 km while the resolution of the north-south features is latitude-dependent. The other improvements are to use a much higher spherical harmonic reference model to improve continuity of gravity anomaly at coastlines and to edit the along-track data using our faith in the V7.2 gravity grid. The agreement with ship gravity measurements has improved from about 4.5 mGal rms for version 7.2 to about 4.0 mGal for version 9.1. major improvements occur over the peaks of large seamounts in the deep oceans where version 7.2 gravity underestimated peaks by as much as 20 mGal.
- Lydie Sichoix joined our project as a Post Doctorate Researcher in July of 1998. She has spent 50% time on the project and has made significant progress in three main areas: First she has been working with the Geological Data Center at Scripps to identify and correct bad soundings in the GEODAS-3 data. Second she has written codes to evaluate and despoke both shipboard gravity and ship soundings through a comparison with our 2-minute gravity and topography grids. Third she has used cleaned depth soundings in selected areas of scientific interest to estimate elastic thickness. The areas include: Easter-Salas Y Gomez Seamounts, Musician Seamounts, Puka Puka Ridges, Foundation Seamounts and the Pacific/Antarctic Ridge.

Meetings and Publications:

- Sandwell, D. T., W.H.F. Smith, Bathymetric Estimation,, Chapter 11 in *Satellite Altimetry and Earth Sciences*, ed., A. Cazenave, L.L. Fu, to be published by Academic Press in 1999, see http://topex.ucsd.edu/marine_topo/chapter11/estimation.html.
- Sichoix, L., D.T. Sandwell, and A. Bonneville, Geomorphological and geophysical classification of the linear elongated volcanic ridges in the Pacific Ocean, *EOS Trans., AGU*, v. 79, no. 45, p. F905, 1998
- Smith, W. H. F., D. T. Sandwell, An improved procedure for estimating marine gravity anomalies from satellite altimetry, *EOS Trans., AGU*, v. 79, no. 45, p. F214, 1998.

Progress for Year 3 7/99-6/00

We gathered ship soundings from all possible sources. New data sets include: data from French cruises New Caledonia, French Polynesia and Foundation Seamounts; new multibeam data from the SIO and Lamont archives; data related to coral reefs; various other shallow water bathymetry.

- Explore three methods for bathymetric prediction; the original Nettleton approach, the parameter estimation approach (elastic thickness, density) and a new inverse theory approach. Our objectives are to both extract scientifically valuable information from the gravity/topography relationship and to produce a 1-minute resolution bathymetric grid that matches known depths.
- Scientific studies: Comparative studies of linear volcanic ridges in terms of both seafloor morphology and gravity/topography relationship; global analysis of lithospheric thickness at large seamounts.

Deliver: Scientific papers on gravity field recovery from satellite altimetry; bathymetric prediction and seafloor/lithospheric characteristics; Presentations at scientific meeting.

Progress for Year 4 7/00-6/01 (no cost extension)

During the past year, there have been significant new contributions of depth soundings which were used for construction of version 8.2 of a global 2-minute bathymetric grid.

These include:

- significant contributions to the NOAA National Geophysical Data Center from oceanographic institutions throughout the world;
- contributions from the French facility IFREMER of centerbeam echo sounder data from more than 80 expeditions of RV Atalante;
- contributions from the Canadian Geological Survey;
- and contributions from the US Polar Research Program from their facility ships.

In addition to the construction of a global grid at 2-minute resolution, the oceanographic community has recently become interested in estimates of seafloor roughness to be used for tuning TOPEX/Poseidon tide models. We have constructed roughness grids and made them available on our ftp site.